LEVEL II SCOUR ANALYSIS FOR BRIDGE 36 (RANDTH00480036) on TOWN HIGHWAY 48, crossing SNOWS BROOK, RANDOLPH, VERMONT

U.S. Geological Survey
Open-File Report 96-641

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

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By SCOTT A. OLSON

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Pembroke, New Hampshire

1996

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	MC	main channel
D_{50}	median diameter of bed material	RAB	right abutment
DS	downstream	RABUT	face of right abutment
elev.	elevation	RB	right bank
f/p	flood plain	ROB	right overbank
ft^2	square feet	RWW	right wingwall
ft/ft	feet per foot	TH	town highway
JCT	junction	UB	under bridge
LAB	left abutment	US	upstream
LABUT	face of left abutment	USGS	United States Geological Survey
LB	left bank	VTAOT	Vermont Agency of Transportation
LOB	left overbank	WSPRO	water-surface profile model

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 36 (RANDTH00480036) ON TOWN HIGHWAY 48, CROSSING SNOWS BROOK, RANDOLPH, VERMONT

***By* Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure RANDTH00480036 on town highway 48 crossing Snows Brook, Randolph, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province of central Vermont. The 3.72-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Snows Brook has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 27 ft and an average channel depth of 3 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 72.7 mm (0.238 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 9, 1994, indicated that the reach was laterally unstable.

The town highway 48 crossing of Snows Brook is a 32-ft-long, two-lane bridge consisting of one 28-foot concrete span (Vermont Agency of Transportation, written communication, July 29, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is 45 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.1 to 11.6 ft. The worst-case abutment scour occurred at the incipient-overtopping discharge, which was 50 cfs lower than the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Randolph Center, VT. Quadrangle, 1:24,000, 1981
Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number RANDTH00480036 *Stream* Snows Brook

County Orange *Road* TH48 *District* 4

Description of Bridge

Bridge length 32 *ft* *Bridge width* 23.6 *ft* *Max span length* 28 *ft*

Alignment of bridge to road (on curve or straight) Straight

Abutment type Vertical, concrete *Embankment type* Sloping

Stone fill on abutment? No *Date of inspection* 8/9/94

Description of stone fill Type-2 (less than 36 inches diameter) at the upstream end of the upstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. The abutment footings are exposed.

Is bridge skewed to flood flow according to Y *survey?* Y *Angle* 40

Severe channel bend at the upstream face of the bridge which impacts the left abutment.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	11/08/94	0	0
Level II	11/08/94	--	--

Potential for debris Moderate. There is some debris accumulation (a few logs and branches) in the immediate channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) The left abutment and upstream left wingwall have a severe impact angle.

Description of the Geomorphic Setting

General topography The channel is located within a narrow, moderate relief, upland valley with no flood plains.

Geomorphic conditions at bridge site: downstream (DS), upstream (US)

Date of inspection 11/08/94

DS left: Steep channel bank to a narrow terrace and steep valley wall.

DS right: Steep channel bank to a narrow terrace and steep valley wall.

US left: Steep valley wall

US right: Steep channel bank to a narrow terrace and steep valley wall.

Description of the Channel

Average top width 27 ***ft*** ***Average depth*** 3 ***ft***

Predominant bed material Cobbles ***Bank material*** Gravel to Boulders

Small, incised, and sinuous with semi-alluvial to non-alluvial channel boundaries

8/9/94

Vegetative co Forested with gravel roadway on the narrow terrace

DS left: Forested

DS right: Forested

US left: Forested with gravel roadway on the narrow terrace

US right:

Do banks appear stable? N ***If not, describe location and type of instability and date of observation.***

August 9, 1994. There are cut banks and some evidence of channel migration in the downstream reach.

Describe any obstructions in channel and date of observation. None. August 9, 1994.

Hydrology

Drainage area 3.72 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

--

Calculated Discharges

Q100 750 ***ft***^{3}***/s*** ***Q500*** 1100 ***ft***^{3}***/s***

The 100- and 500-year discharges were selected from a range of discharges defined by several empirical methods applicable to a watershed of this size in this region (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is the top of a metal stake in the upstream right end of the base of the concrete bridge railing (elev. 507.25 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT	0	1	Exit section
FULLV	30	2	Downstream Full-valley section (Templated from EXIT)
BRDG	30	1	Bridge section
RDWAY	48	1	Road Grade section
APTEM	73	1	Approach section as surveyed (Used as a template)
APPRO	82	2	Modelled Approach section (Templated from APTEM)

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.050 to 0.065.

Normal depth at the exit section (EXIT) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.030 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1981).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.008 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 506.2 *ft*
Average low steel elevation 502.9 *ft*

100-year discharge 750 *ft³/s*
Water-surface elevation in bridge opening 503.0 *ft*
Road overtopping? N *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 113 *ft²*
Average velocity in bridge opening 6.6 *ft/s*
Maximum WSPRO tube velocity at bridge 8.0 *ft/s*

Water-surface elevation at Approach section with bridge 504.0 *ft*
Water-surface elevation at Approach section without bridge 501.1 *ft*
Amount of backwater caused by bridge 2.9 *ft*

500-year discharge 1100 *ft³/s*
Water-surface elevation in bridge opening 503.0 *ft*
Road overtopping? Y *Discharge over road* 18 *ft³/s*
Area of flow in bridge opening 113 *ft²*
Average velocity in bridge opening 9.6 *ft/s*
Maximum WSPRO tube velocity at bridge 11.6 *ft/s*

Water-surface elevation at Approach section with bridge 506.3 *ft*
Water-surface elevation at Approach section without bridge 501.9 *ft*
Amount of backwater caused by bridge 4.4 *ft*

Incipient overtopping discharge 1050 *ft³/s*
Water-surface elevation in bridge opening 503.0 *ft*
Area of flow in bridge opening 113 *ft²*
Average velocity in bridge opening 9.3 *ft/s*
Maximum WSPRO tube velocity at bridge 11.2 *ft/s*

Water-surface elevation at Approach section with bridge 505.9 *ft*
Water-surface elevation at Approach section without bridge 501.8 *ft*
Amount of backwater caused by bridge 4.1 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). For each of the modelled discharges, there was unsubmerged orifice flow at the bridge. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996) . The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.8	0.5
Depth to armoring	0.5	3.7	3.1
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	9.0	11.2	11.6
Right abutment	6.1	6.4	6.4
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.2	2.5	2.3
Right abutment	1.2	2.5	2.3
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

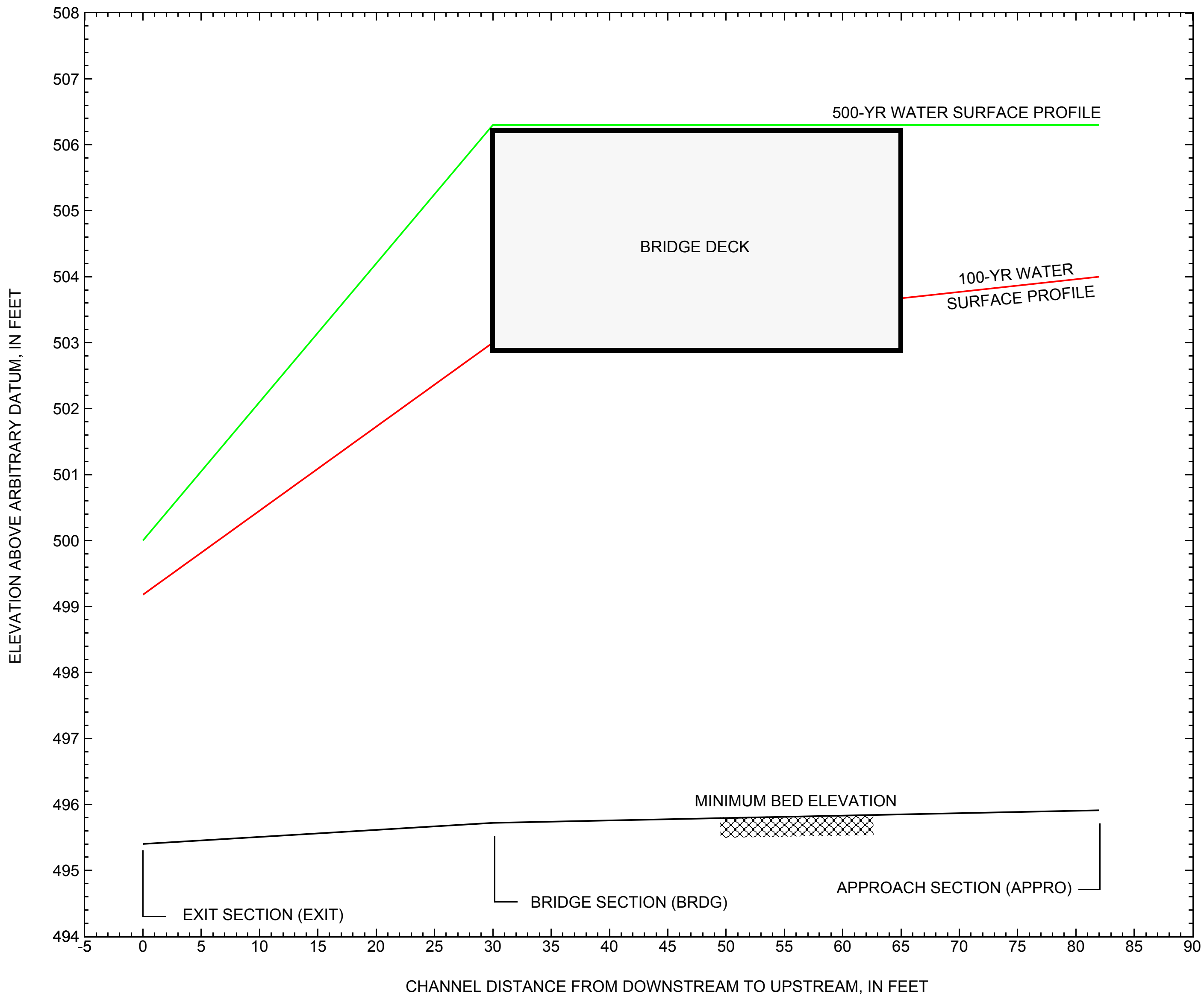

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RANDTH00480036 on town highway 48, crossing Snows Brook, Randolph, Vermont.

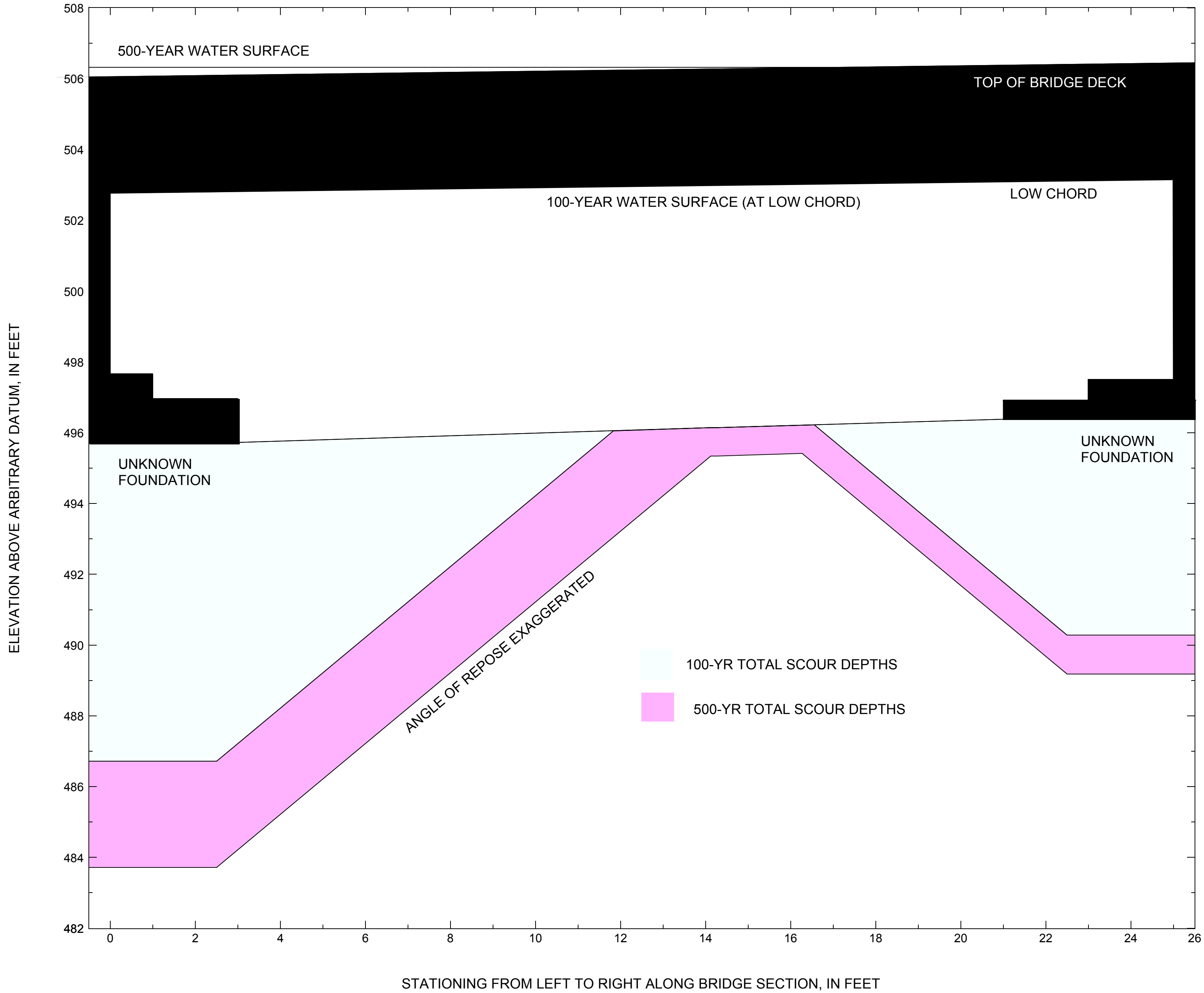

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RANDTH00480036 on town highway 48, crossing Snows Brook, Randolph, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RANDTH00480036 on Town Highway 48, crossing Snows Brook, Randolph, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 750 cubic-feet per second											
Left abutment	0	--	502.8	--	495.7	0.0	9.0	--	9.0	486.7	--
Right abutment	25	--	503.0	--	496.4	0.0	6.1	--	6.1	490.3	--

1. Measured along the face of the most constricting side of the bridge.
2. Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure RANDTH00480036 on Town Highway 48, crossing Snows Brook, Randolph, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 1,100 cubic-feet per second											
Left abutment	0	--	502.8	--	495.7	0.8	11.2	--	12.0	483.7	--
Right abutment	25	--	503.0	--	496.4	0.8	6.4	--	7.2	489.2	--

1. Measured along the face of the most constricting side of the bridge.
2. Arbitrary datum for this study.

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1            HYDRAULIC ANALYSIS
T2            Randolph Bridge #36
T3            USGS  Pembroke, NH 6/6/96
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q             750 1100 1050
SK            0.030 0.030 0.030
*
XS   EXIT     0
GR           -28., 504.17     -24., 503.07     -18., 499.96     -13., 498.62
GR           -11., 498.06      -8., 497.45      -7., 496.74       0., 495.85
GR             5., 495.84      12., 495.80      15., 495.40      19., 495.80
GR            20., 496.45      23., 498.86      26., 502.21      29., 503.22
GR            36., 504.52
N             0.065
*
XS   FULLV    30 * * * 0.011
*
BR   BRDG     30 502.9 45
GR             0., 502.75       0., 497.65       1., 497.64       1., 496.96
GR             3., 496.93       3., 495.72      15., 496.17      21., 496.38
GR            22., 496.90      23., 496.87      23., 497.26      24., 497.48
GR            25., 502.96       0., 502.75
N             0.050
CD            4 35.3 2 506.3 30
*
XR   RDWAY    48 24 2
GR           -21., 511.08     -10., 505.6        0., 505.90       0., 509.06
GR            31., 509.56      31., 506.58      33., 506.58      54., 506.86
GR            76., 507.23     110., 507.93     148., 508.95
BP             0
*
XT   APTEM    73
GR           -21., 511.08     -12., 507.36      -7., 500.47       0., 498.95
GR             2., 498.49       3., 497.11       5., 496.77      10., 495.84
GR            14., 496.75      17., 497.30      17., 499.53      18., 500.37
GR            19., 503.99      23., 506.66     150., 509.
*
AS   APPRO    82
GT            0.07
N             0.065
*
HP 1 BRDG 502.96 1 502.96
HP 2 BRDG 502.96 * * 750
HP 1 APPRO 503.95 1 503.95
HP 2 APPRO 503.95 * * 750
*
HP 1 BRDG 502.96 1 502.96
HP 2 BRDG 502.96 * * 1086
HP 2 RDWAY 506.25 * * 18
HP 1 APPRO 506.25 1 506.25
HP 2 APPRO 506.25 * * 1100
*
HP 1 BRDG 502.96 1 502.96
HP 2 BRDG 502.96 * * 1050
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
           HYDRAULIC ANALYSIS
           Randolph Bridge #36
           USGS  Pembroke, NH 6/6/96
          *** RUN DATE & TIME: 06-06-96  13:02
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDG ;  SRD =      30.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     113.    5973.     0.    48.                    4932162.
   502.96          113.    5973.     0.    48.  1.00     0.   25.4932162.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDG ;  SRD =      30.
         WSEL     LEW     REW    AREA        K        Q    VEL
       502.96     0.0    25.0   112.9    5973.     750.   6.64
 X STA.         0.0         2.6        4.1        5.2        6.2        7.3
   A(I)             10.1        7.1        5.5        5.3        5.0
   V(I)             3.72       5.27       6.82       7.13       7.48

 X STA.         7.3         8.3        9.2       10.2       11.2       12.2
   A(I)              4.9        4.8        4.8        4.7        4.7
   V(I)             7.68       7.86       7.83       7.96       7.99

 X STA.        12.2        13.2       14.2       15.2       16.2       17.2
   A(I)              4.7        4.7        4.7        4.9        4.9
   V(I)             7.95       7.98       7.92       7.69       7.63

 X STA.        17.2        18.3       19.4       20.6       22.0       25.0
   A(I)              5.0        5.3        5.5        6.4       10.0
   V(I)             7.43       7.09       6.80       5.86       3.76

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     158.    9617.    28.    37.                       2115.
   503.95          158.    9617.    28.    37.  1.00    -9.    19.   2115.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.
         WSEL     LEW     REW    AREA        K        Q    VEL
       503.95    -9.5    19.0   158.1    9617.     750.   4.74
 X STA.        -9.5        -4.5       -2.1       -0.3        1.3        2.8
   A(I)             13.6        9.8        8.5        8.1        8.7
   V(I)             2.76       3.84       4.40       4.65       4.33

 X STA.         2.8         3.9        4.8        5.7        6.6        7.4
   A(I)              7.1        6.6        6.4        6.4        6.3
   V(I)             5.29       5.68       5.84       5.89       5.95

 X STA.         7.4         8.2        9.0        9.8       10.6       11.4
   A(I)              6.0        6.2        6.1        6.3        6.4
   V(I)             6.20       6.08       6.11       5.97       5.84

 X STA.        11.4        12.2       13.2       14.3       15.5       19.0
   A(I)              6.6        7.0        7.7        8.8       15.4
   V(I)             5.66       5.33       4.87       4.24       2.43
```

```
          HYDRAULIC ANALYSIS
          Randolph Bridge #36
          USGS  Pembroke, NH 6/6/96
         *** RUN DATE & TIME: 06-06-96  13:02
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDG ;  SRD =      30.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     113.    5973.     0.    48.                      4932162.
 502.96          113.    5973.     0.    48.  1.00     0.    25.4932162.

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDG ;  SRD =      30.
      WSEL     LEW     REW    AREA        K        Q    VEL
    502.96     0.0    25.0   112.9    5973.    1086.   9.61
X STA.         0.0         2.6        4.1        5.2        6.2        7.3
  A(I)            10.1        7.1        5.5        5.3        5.0
  V(I)            5.39       7.64       9.88      10.32      10.84

X STA.         7.3         8.3        9.2       10.2       11.2       12.2
  A(I)             4.9        4.8        4.8        4.7        4.7
  V(I)           11.12      11.39      11.35      11.53      11.57

X STA.        12.2        13.2       14.2       15.2       16.2       17.2
  A(I)             4.7        4.7        4.7        4.9        4.9
  V(I)           11.50      11.55      11.47      11.14      11.04

X STA.        17.2        18.3       19.4       20.6       22.0       25.0
  A(I)             5.0        5.3        5.5        6.4       10.0
  V(I)           10.77      10.26       9.85       8.48       5.45

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      48.
      WSEL     LEW     REW    AREA        K        Q    VEL
    506.25   -11.3     0.0     5.4      74.      18.   3.32
X STA.       -11.3       -10.1       -9.7       -9.3       -8.9       -8.5
  A(I)             0.4        0.3        0.2        0.2        0.2
  V(I)            2.36       3.40       3.76       3.83       3.82

X STA.        -8.5        -8.1       -7.7       -7.3       -6.9       -6.4
  A(I)             0.2        0.2        0.2        0.2        0.2
  V(I)            3.85       3.86       3.77       3.75       3.61

X STA.        -6.4        -6.0       -5.5       -5.0       -4.4       -3.9
  A(I)             0.2        0.3        0.3        0.3        0.3
  V(I)            3.65       3.53       3.45       3.33       3.37

X STA.        -3.9        -3.2       -2.6       -1.9       -1.1        0.0
  A(I)             0.3        0.3        0.3        0.3        0.4
  V(I)            3.15       3.10       3.02       2.86       2.33

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     229.   15903.    33.    43.                         3404.
 506.25          229.   15903.    33.    43.  1.00   -11.    22.   3404.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.
      WSEL     LEW     REW    AREA        K        Q    VEL
    506.25   -11.1    22.3   229.1   15903.    1100.   4.80
X STA.       -11.1        -5.6       -3.4       -1.7       -0.2        1.3
  A(I)            20.1       13.4       11.5       11.0       10.5
  V(I)            2.74       4.10       4.77       5.01       5.23

X STA.         1.3         2.7        3.8        4.7        5.7        6.6
  A(I)            11.2        9.7        9.1        9.1        8.7
  V(I)            4.92       5.66       6.05       6.03       6.31

X STA.         6.6         7.5        8.4        9.3       10.2       11.1
  A(I)             8.8        8.9        8.9        9.2        9.3
  V(I)            6.26       6.15       6.20       6.01       5.94

X STA.        11.1        12.1       13.2       14.4       15.9       22.3
  A(I)             9.8       10.7       11.5       13.7       24.1
  V(I)            5.63       5.13       4.78       4.03       2.28
```

```
          HYDRAULIC ANALYSIS
          Randolph Bridge #36
          USGS  Pembroke, NH 6/6/96
         *** RUN DATE & TIME: 06-06-96  13:02
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRDG ;  SRD =      30.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     113.    5973.     0.    48.                    4932162.
  502.96          113.    5973.     0.    48.  1.00     0.    25.4932162.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRDG ;  SRD =      30.
        WSEL     LEW     REW    AREA        K        Q    VEL
      502.96     0.0    25.0   112.9    5973.    1050.   9.30
X STA.        0.0         2.6         4.1         5.2         6.2         7.3
  A(I)            10.1         7.1         5.5         5.3         5.0
  V(I)            5.21        7.38        9.55        9.98       10.48

X STA.        7.3         8.3         9.2        10.2        11.2        12.2
  A(I)             4.9         4.8         4.8         4.7         4.7
  V(I)           10.75       11.01       10.97       11.14       11.19

X STA.       12.2        13.2        14.2        15.2        16.2        17.2
  A(I)             4.7         4.7         4.7         4.9         4.9
  V(I)           11.12       11.17       11.09       10.77       10.68

X STA.       17.2        18.3        19.4        20.6        22.0        25.0
  A(I)             5.0         5.3         5.5         6.4        10.0
  V(I)           10.41        9.92        9.52        8.20        5.27

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      82.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     216.   14711.    33.    42.                        3162.
  505.86          216.   14711.    33.    42.  1.00   -11.    22.   3162.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      82.
        WSEL     LEW     REW    AREA        K        Q    VEL
      505.86   -10.9    21.7   216.2   14711.    1050.   4.86
X STA.      -10.9        -5.4        -3.3        -1.5         0.0         1.4
  A(I)            19.2        12.2        11.4        10.3         9.9
  V(I)            2.73        4.29        4.62        5.11        5.33

X STA.        1.4         2.9         3.9         4.9         5.8         6.7
  A(I)            11.0         8.9         8.6         8.6         8.3
  V(I)            4.77        5.92        6.10        6.09        6.36

X STA.        6.7         7.6         8.5         9.3        10.2        11.1
  A(I)             8.3         8.4         8.4         8.6         8.7
  V(I)            6.34        6.23        6.27        6.08        6.02

X STA.       11.1        12.1        13.1        14.3        15.7        21.7
  A(I)             9.4         9.9        10.8        12.5        22.9
  V(I)            5.56        5.33        4.85        4.21        2.30
```

WSPRO OUTPUT FILE (continued)

```
           HYDRAULIC ANALYSIS
           Randolph Bridge #36
           USGS  Pembroke, NH 6/6/96
          *** RUN DATE & TIME: 06-06-96  13:02

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT :XS   ******   -15.     102.  0.85 *****  500.02  498.75    750.  499.18
        0. ******    23.    4329.  1.00 ***** *******    0.80    7.38

FULLV:FV      30.   -17.     126.  0.55  0.66  500.67 *******    750.  500.12
       30.    30.    24.    5891.  1.00  0.00   -0.01    0.60    5.95
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.91     501.12     500.90

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   499.62     511.15    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   499.62     511.15     500.90

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.61

APPRO:AS      52.    -7.      81.  1.32  1.37  502.43  500.90    750.  501.11
       82.    52.    18.    3619.  1.00  0.39    0.00    0.91    9.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   500.24     503.29     503.57     502.90

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRDG :BR      30.     0.     113.  0.69 *****  503.65  500.24    750.  502.96
       30. ******    25.    5973.  1.00 ***** *******    0.55    6.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.443  0.000  502.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      48.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS      17.    -9.     158.  0.35  0.17  504.30  500.90    750.  503.95
       82.    17.    19.    9610.  1.00  1.51    0.00    0.35    4.75

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   503.78

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT :XS       0.   -15.    23.    750.    4329.     102.    7.38  499.18
   FULLV:FV      30.   -17.    24.    750.    5891.     126.    5.95  500.12
   BRDG :BR      30.     0.    25.    750.    5973.     113.    6.64  502.96
   RDWAY:RG      48.**************      0.*****************    2.00********
   APPRO:AS      82.    -9.    19.    750.    9610.     158.    4.75  503.95

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT :XS    498.75    0.80  495.40  504.52************  0.85  500.02  499.18
   FULLV:FV  ********    0.60  495.73  504.85  0.66  0.00  0.55  500.67  500.12
   BRDG :BR    500.24    0.55  495.72  502.96************  0.69  503.65  502.96
   RDWAY:RG  ****************  505.60  511.08************  0.13  507.09********
   APPRO:AS    500.90    0.35  495.91  511.15  0.17  1.51  0.35  504.30  503.95
```

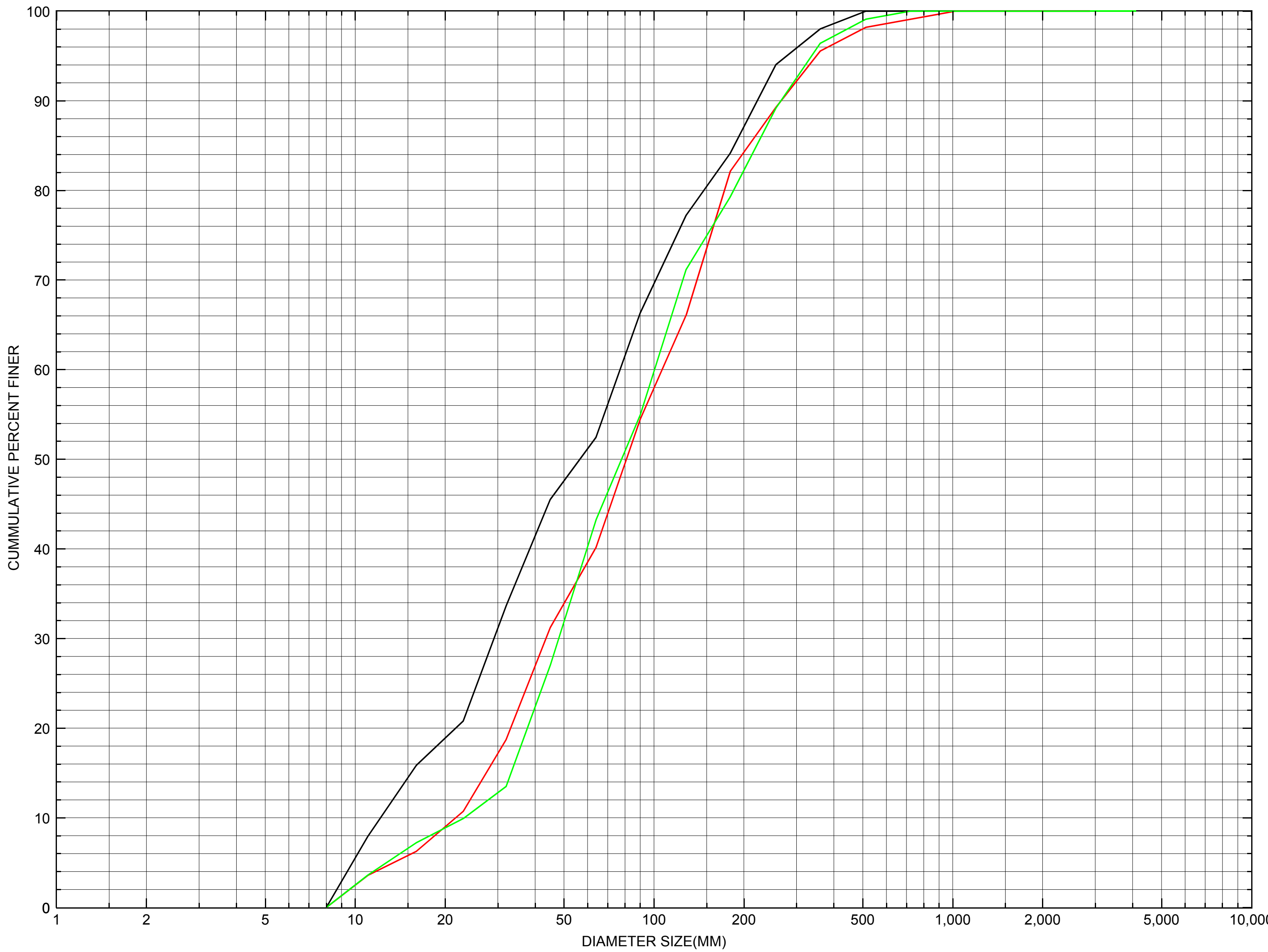
WSPRO OUTPUT FILE (continued)

```
           HYDRAULIC ANALYSIS
           Randolph Bridge #36
           USGS  Pembroke, NH 6/6/96
          *** RUN DATE & TIME: 06-06-96  13:02

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT :XS   ******   -18.     133.  1.07 *****  501.02  499.51   1100.  499.95
        0. ******    24.    6350.  1.00 ***** *******    0.82    8.28

FULLV:FV      30.   -19.     162.  0.72  0.67  501.68 *******   1100.  500.96
       30.    30.    25.    8509.  1.00  0.00   -0.02    0.62    6.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.98     501.87     501.83

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   500.46     511.15    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   500.46     511.15     501.83

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.59

APPRO:AS      52.    -8.     101.  1.84  1.48  503.71  501.83   1100.  501.87
       82.    52.    18.    5012.  1.00  0.56    0.00    0.98   10.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   501.37     504.81     505.10     502.90

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRDG :BR      30.     0.     113.  1.44 *****  504.40  501.34   1086.  502.96
       30. ******    25.    5973.  1.00 ***** *******    0.80    9.62

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.500  0.000  502.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      48.    28.  0.13  0.36  506.48    0.00     18.  506.25

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     18.    11.   -11.     0.   0.7   0.5   3.5   3.4   0.7   2.8
   RT:      0.    26.    31.    57.   0.3   0.2   2.7   4.4   0.4   2.7

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS      17.   -11.     229.  0.36  0.21  506.61  501.83   1100.  506.25
       82.    17.    22.   15908.  1.00  1.44    0.00    0.32    4.80
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT :XS       0.   -18.    24.   1100.    6350.     133.    8.28  499.95
   FULLV:FV      30.   -19.    25.   1100.    8509.     162.    6.80  500.96
   BRDG :BR      30.     0.    25.   1086.    5973.     113.    9.62  502.96
   RDWAY:RG      48.*******    18.     18.*********       0.    2.00  506.25
   APPRO:AS      82.   -11.    22.   1100.   15908.     229.    4.80  506.25

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT :XS    499.51    0.82  495.40  504.52************  1.07  501.02  499.95
   FULLV:FV  ********    0.62  495.73  504.85  0.67  0.00  0.72  501.68  500.96
   BRDG :BR    501.34    0.80  495.72  502.96************  1.44  504.40  502.96
   RDWAY:RG  ****************  505.60  511.08  0.13******  0.36  506.48  506.25
   APPRO:AS    501.83    0.32  495.91  511.15  0.21  1.44  0.36  506.61  506.25
```

```
           HYDRAULIC ANALYSIS
           Randolph Bridge #36
           USGS  Pembroke, NH 6/6/96
          *** RUN DATE & TIME: 06-06-96  13:02

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT :XS   ******   -18.     129.  1.04 *****  500.89  499.42   1050.  499.85
        0. ******    24.    6061.  1.00 ***** *******    0.82    8.17

FULLV:FV      30.   -19.     157.  0.70  0.67  501.54 *******   1050.  500.85
       30.    30.    24.    8140.  1.00  0.00   -0.02    0.62    6.69
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.97     501.78     501.70

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   500.35     511.15    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   500.35     511.15     501.70

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.59

APPRO:AS      52.    -8.      99.  1.76  1.46  503.54  501.70   1050.  501.77
       82.    52.    18.    4823.  1.00  0.53    0.00    0.97   10.65
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   501.23     504.59     504.88     502.90

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRDG :BR      30.     0.     113.  1.33 *****  504.29  501.21   1045.  502.96
       30. ******    25.    5973.  1.00 ***** *******    0.77    9.26

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.498  0.000  502.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      48.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS      17.   -11.     216.  0.37  0.21  506.23  501.70   1050.  505.86
       82.    17.    22.   14725.  1.00  1.44    0.00    0.33    4.85

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   505.72

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT :XS       0.   -18.    24.   1050.    6061.     129.    8.17  499.85
   FULLV:FV      30.   -19.    24.   1050.    8140.     157.    6.69  500.85
   BRDG :BR      30.     0.    25.   1045.    5973.     113.    9.26  502.96
   RDWAY:RG      48.**************      0.       0.       0.    2.00********
   APPRO:AS      82.   -11.    22.   1050.   14725.     216.    4.85  505.86

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT :XS    499.42    0.82  495.40  504.52************  1.04  500.89  499.85
   FULLV:FV  ********    0.62  495.73  504.85  0.67  0.00  0.70  501.54  500.85
   BRDG :BR    501.21    0.77  495.72  502.96************  1.33  504.29  502.96
   RDWAY:RG  ****************  505.60  511.08************  0.37  506.09********
   APPRO:AS    501.70    0.33  495.91  511.15  0.21  1.44  0.37  506.23  505.86
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure RANDTH00480036, in Randolph, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number RANDTH00480036

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 07 / 29 / 94

Highway District Number *(I - 2; nn)* 04

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 58075

Mile marker *(I - 11; nnn.nnn)* 000000

Waterway *(I - 6)* SNOWS BROOK

Road Name *(I - 7)*: -

Route Number TH048

Vicinity *(I - 9)* 0.3 MI JCT TH 48 + VT 14

Topographic Map Randolph.Center

Hydrologic Unit Code: 01080105

Latitude *(I - 16; nnnn.n)* 43584

Longitude *(i - 17; nnnnn.n)* 72336

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090900360909

Maintenance responsibility *(I - 21; nn)* 03

Maximum span length *(I - 48; nnnn)* 0028

Year built *(I - 27; YYYY)* 1923

Structure length *(I - 49; nnnnnn)* 000032

Average daily traffic, ADT *(I - 29; nnnnnn)* 000100

Deck Width *(I - 52; nn.n)* 236

Year of ADT *(I - 30; YY)* 94

Channel & Protection *(I - 61; n)* 4

Opening skew to Roadway *(I - 34; nn)* 45

Waterway adequacy *(I - 71; n)* 5

Operational status *(I - 41; X)* A

Underwater Inspection Frequency *(I - 92B; XYY)* N

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 001

Vertical clearance from streambed (*nnn.n ft*) 006.5

Number of approach spans *(I - 46; nnnn)* 0000

Waterway of full opening (*nnn.n ft*^{2}) -

Comments:

Structural report of 7/19/93 indicated settlement cracks in the abutment walls with possible undermining during high flows. Embankment erosion was minor. The channel makes a sharp turn before flowing through the bridge. A channel point bar was noted as present against the right abutment.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: ROCKS AND BOULDERS, MUD AND GRAVEL

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

Record flood date *(MM / DD / YY)*: - / / Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q - *(ft/s)*: -

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: LIGHT

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): -%

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): - Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **3.72** mi^2 Lake and pond area **0.07** mi^2

Watershed storage *(ST)* **2** %

Bridge site elevation **740** ft Headwater elevation **1640** ft

Main channel length **3.61** mi

10% channel length elevation **820** ft 85% channel length elevation **1480** ft

Main channel slope *(S)* **244** ft / mi

Watershed Precipitation Data

Average site precipitation ____ in Average headwater precipitation ____ in

Maximum 2yr-24hr precipitation event *(I24,2)* ____ in

Average seasonal snowfall *(Sn)* ____ ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / --

Project Number - Minimum channel bed elevation: -

Low superstructure elevation: USLAB - DSLAB - USRAB - DSRAB -

Benchmark location description:

-
-
-
-

Reference Point (*MSL, Arbitrary, Other*): - Datum (*NAD27, NAD83, Other*): ____

Foundation Type: 4 (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness - Footing bottom elevation: -

If 2: Pile Type: - (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: -

If 3: Footing bottom elevation: -

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:
NO FOUNDATION MATERIAL INFORMATION

Comments:
NO PLANS

Cross-sectional Data

Is cross-sectional data available? N *If no, type ctrl-n xs*

Source (*FEMA, VTAOT, Other*)? -

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Source (*FEMA, VTAOT, Other*)? -

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

U. S. Geological Survey
Bridge Field Data Collection and Processing Form

Qa/Qc Check by: **SAO** Date: **2/14/96**
Computerized by: **EMB** Date: **2/14/96**
Reviewd by: **SAO** Date: **6/25/96**

Structure Number **RANDTH00480036**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **08** / **09** / 19**94**

2. Highway District Number **04** Mile marker **-**

County **ORANGE (017)** Town **RANDOLPH (58075)**

Waterway *(I - 6)* **SNOWS BROOK** Road Name **-**

Route Number **TH048** Hydrologic Unit Code: **01080105**

3. Descriptive comments:

This structure is a concrete T-beam type bridge about 0.3 mile from the intersection of TH48 with VT14.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **2** DS **2** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **32.0** *(feet)* Span length **28.0** *(feet)* Bridge width **23.6** *(feet)*

Road approach to bridge:

8. LB **1** RB **2** *(**0** even, **1**- lower, **2**- higher)*

9. LB **2** RB **2** *(**1**- Paved, **2**- Not paved)*

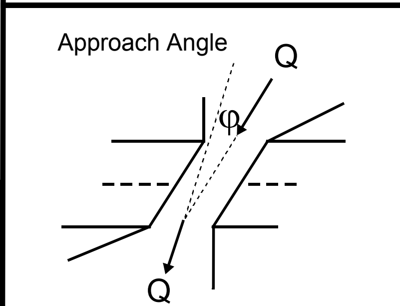
10. Embankment slope (*run / rise in feet / foot*):
US left **-:1** US right **-:1**

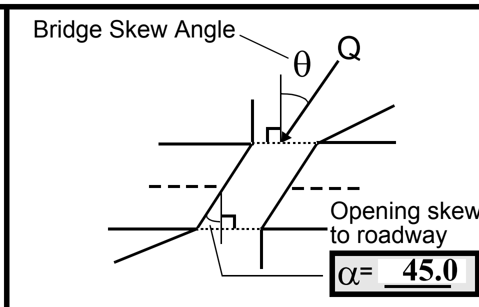
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	1	1
RBUS	3	1	0	-
RBDS	2	1	2	2
LBDS	2	1	2	0

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **40** 16. Bridge skew: **40**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **0** feet **US** *(US, UB, DS)* to **15** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **40** feet **DS** *(US, UB, DS)* to **100** feet **DS**

*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Level II Bridge Type: **4**

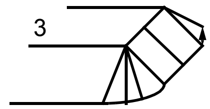
1a- Vertical abutments with wingwalls

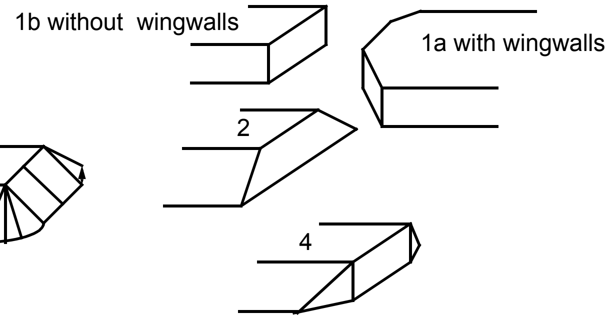
1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.





19. Bridge Deck Comments (surface cover variations, measured bridge and span lengths, bridge type variations, approach overflow width, etc.)

Measured bridge dimensions are 32.0 feet for the bridge length, 28.0 feet for the span length, and 23.5 feet for the roadway width. Surface coverage is mostly forest everywhere. The roadway bisects the area on the left bank downstream and the right bank upstream. The roadway embankment on the right bank upstream forms the right bank of the stream on which there are only some saplings and young trees. The moderate roadwash erosion indicated on the right bank side downstream is channelized by a drainage ditch to a location that is removed from the bridge entering on the downstream right bank. There is protection at the point of inflow to Snows brook but it is not considered road approach protection. There is additional road approach protection near the end of the downstream right wingwall, however. The width of the roadway is 25.0 feet where overflow is expected on the left road approach.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
35.0	**2.0**			**2.0**	**4**	**2**	**5**	**5**	**1**	**1**

23. Bank width **35.0** 24. Channel width **80.0** 25. Thalweg depth **17.0** 29. Bed Material **4**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **1**

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

32. Comments (bank material variation, minor inflows, protection extent, etc.):

The right bank protection extends 30 feet beyond the upstream end of the right wingwall. The bank material is composed of boulders predominantly with some cobbles embedded in sand. The bed material is composed of cobbles with a few boulders embedded in sand and gravel.

33. Point/Side bar present? N (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: - 35. Mid-bar width: -

36. Point bar extent: - feet - (US, UB) to - feet - (US, UB, DS) positioned - %LB to - %RB

37. Material: -

38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):

NO POINT BARS

39. Is a cut-bank present? N (Y or if N type ctrl-n cb) 40. Where? - (LB or RB)

41. Mid-bank distance: - 42. Cut bank extent: - feet - (US, UB) to - feet - (US, UB, DS)

43. Bank damage: - (**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

44. Cut bank comments (eg. additional cut banks, protection condition, etc.):

NO CUT BANKS

45. Is channel scour present? N (Y or if N type ctrl-n cs) 46. Mid-scour distance: -

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

48. Scour comments (eg. additional scour areas, local scouring process, etc.):

NO CHANNEL SCOUR

49. Are there major confluences? N (Y or if N type ctrl-n mc) 50. How many? -

51. Confluence 1: Distance - 52. Enters on - (LB or RB) 53. Type - (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance - Enters on - (LB or RB) Type - (**1**- perennial; **2**- ephemeral)

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 2 RB ______ (**1**- natural bank; **2**- abutment; **3**- artificial levee)

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
14.0		1.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

Bed and bank Material: ***0****- organics;* ***1****- silt / clay, < 1/16mm;* ***2****- sand, 1/16 - 2mm;* ***3****- gravel, 2 - 64mm;* ***4****- cobble, 64 - 256mm;* ***5****- boulder, > 256mm;* ***6****- bedrock;* ***7****- manmade*

Bank Erosion: ***0****- not evident;* ***1****- light fluvial;* ***2****- moderate fluvial;* ***3****- heavy fluvial / mass wasting*

64. Comments (bank material variation, minor inflows, protection extent, etc.):

4

There is no protection on the abutment walls. The bed material is composed of cobbles embedded in sand and gravel.

65. **Debris and Ice** Is there debris accumulation? ____ *(Y or N)* 66. Where? **Y** ____ *(1- Upstream; 2- At bridge; 3- Both)*

67. Debris Potential **1** ____ *(1- Low; 2- Moderate; 3- High)* 68. Capture Efficiency **2** ____ *(1- Low; 2- Moderate; 3- High)*

69. Is there evidence of ice build-up? **2** ____ *(Y or N)* Ice Blockage Potential **N** ____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Some debris has accumulated in the channel upstream. The channel gradient is moderate and the abutments constrict the channel. In addition, the channel makes a sharp bend right to pass through the bridge. The combined effect of these factors probably lends to a moderate capture efficiency. With high percentages of tree coverage on the banks upstream but yet a stable channel configuration, the potential for debris pro-

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT	duc-	tion	is	mod-	erate	.	10	90.0
RABUT	90	2	2			0.5	2.0	17.5

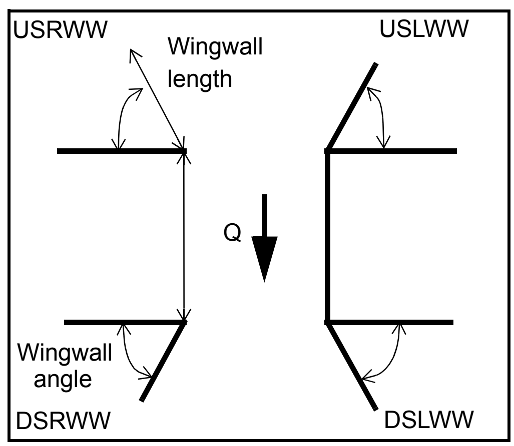
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

1
-
90
2
2
0.0
1.0
1
The scour depth indicated is localized and extends the length of the left abutment.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						17.5	
USRWW:						2.0	
DSLWW:					Y	36.0	
DSRWW:	1		2		0.5	34.5	



Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	2.0	2	Y	0.5	1	0.5	-	2
Condition	Y	0.0	1	2.0	2	0	2	0
Extent	1	0.5	2	Y	0.0	-	1	-

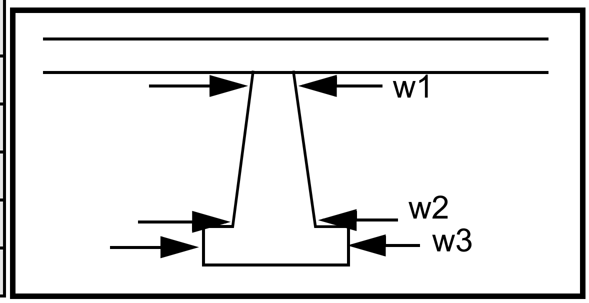
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
0
-
-
-
-
-
-
-
-
0

Piers:

84. Are there piers? _-_ *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	125.0	5.0		13.0	11.5	40.0
Pier 2	7.5	9.5	-	130.0	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	-	left	foot-	local	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	0	wing	ing	ized	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	-	wall	and	scou	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	-	the	abou	r on	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	The	most	t 0.5	the	*Y- yes; N- no*
91. Attack ∠ (BF)	flow	with	feet	upst	
92. Pushed	is	almo	of	ream	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	impa	st 2	chan	left	
95. Cross-members	cting	feet	nel	wing	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	the	of	scou	wall	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	upst	expo	ring.	is	
98. Exposure depth	ream	sed	The	restr	

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):

icted to the area where the wingwall meets the left abutment wall. Likewise, the localized scour depth indicated on the downstream left wingwall is restricted to the area where the wingwall meets the left abutment wall. The riprap protection indicated on the right bank upstream overlaps a 10 foot long, field stone, dry masonry wall that extends upstream from the end of the wingwall and further protects the road embankment.

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	N	-	-	-	-	-

Bank width (BF) -   Channel width (Amb) -   Thalweg depth (Amb) -   Bed Material -

Bank protection type (Qmax): LB - RB -   Bank protection condition: LB - RB -

SRD - Section ref. dist. to US face   *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

Comments (eg. bank material variation, minor inflows, protection extent, etc.):

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

101. Is a drop structure present? - *(Y or N, if N type ctrl-n ds)*   102. Distance: - feet

103. Drop: - feet   104. Structure material: - *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):

-
-
-
-
-
-

106. Point/Side bar present? -____ *(Y or N. if N type ctrl-n pb)* Mid-bar distance: -_____ Mid-bar width: -_____

Point bar extent: -_____ feet -____ *(US, UB, DS)* to -_____ feet -____ *(US, UB, DS)* positioned -____ %LB to -_____ %RB

Material: -_____

Point or side bar comments (Circle Point or Side; note additional bars, material variation, status, etc.):

-
-
-
-

Is a cut-bank present? -____ *(Y or if N type ctrl-n cb)* Where? NO____ *(LB or RB)* Mid-bank distance: PIE____

Cut bank extent: RS____ feet ____ *(US, UB, DS)* to _____ feet ____ *(US, UB, DS)*

Bank damage: _____ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

Cut bank comments (eg. additional cut banks, protection condition, etc.):

Is channel scour present? _____ *(Y or if N type ctrl-n cs)* Mid-scour distance: 4______

Scour dimensions: Length 4_____ Width 2_____ Depth: 3_____ Positioned 0____ %LB to 2____ %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):

4
0
0
-

Are there major confluences? -____ *(Y or if N type ctrl-n mc)* How many? Ther____

Confluence 1: Distance e is a____ Enters on min____ *(LB or RB)* Type or____ *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance stor____ Enters on m____ *(LB or RB)* Type drai____ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

nage ditch that enters the main channel on the right bank about 50 feet downstream. The bank erosion indicated above begins where the channel makes a sharp left bend about 30 feet downstream of the bridge. The

F. Geomorphic Channel Assessment

107. Stage of reach evolution left____

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

bank material is sand mostly with some silt and clay and gravel while the right bank material is gravel mostly with some sand and a few embedded boulders. The bed material is composed of cobbles embedded in sand and gravel.

109. G. Plan View Sketch

\- N

point bar	pb	debris		flow	Q	stone wall	
cut-bank	cb	rip rap or stone fill		cross-section		other wall	
scour hole				ambient channel			

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: RANDTH00480036 Town: Randolph
Road Number: TH48 County: Orange
Stream: Snows Brook

Initials SAO Date: 6/6/96 Checked:

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	750	1100	1050
Main Channel Area, ft2	158	229	216
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	28	33	33
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.238	0.238	0.238
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.6	6.9	6.5
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	9617	15903	14711
Conveyance, main channel	9617	15903	14711
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	750.0	1100.0	1050.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	4.7	4.8	4.9
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.3	9.6	9.5
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	158	229	216
Main channel width, ft	28	33	33
y1, main channel depth, ft	5.64	6.94	6.55

Bridge Section			
(Q) total discharge, cfs	750	1100	1050
(Q) discharge thru bridge, cfs	750	1086	1050
Main channel conveyance	5973	5973	5973
Total conveyance	5973	5973	5973
Q2, bridge MC discharge,cfs	750	1086	1050
Main channel area, ft2	113	113	113
Main channel width (skewed), ft	17.7	17.7	17.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	17.7	17.7	17.7
y_bridge (avg. depth at br.), ft	6.38	6.38	6.38
Dm, median (1.25*D50), ft	0.2975	0.2975	0.2975
y2, depth in contraction,ft	4.34	5.96	5.79
ys, scour depth (y2-ybridge), ft	-2.04	-0.42	-0.59
ys, scour depth (y2-yfullv), ft	0.69	1.47	1.41

Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	750	1086	1050
Vc, critical velocity, ft/s	9.3	9.6	9.5
Vc, critical velocity, m/s	2.834502	2.925937	2.895459
Main channel width (skewed), ft	17.7	17.7	17.7
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	17.7	17.7	17.7
qbr, unit discharge, ft^2/s	42.37288	61.35593	59.32203
qbr, unit discharge, m^2/s	3.936185	5.699596	5.510659
Area of full opening, ft^2	112.9	112.9	112.9
Hb, depth of full opening, ft	6.378531	6.378531	6.378531
Hb, depth of full opening, m	1.944081	1.944081	1.944081
Fr, Froude number MC	0.55	0.8	0.77
Cf, Fr correction factor (<=1.0)	1	1	1
Elevation of Low Steel, ft	502.85	502.85	502.85
Elevation of Bed, ft	496.4715	496.4715	496.4715
Elevation of approach WS, ft	503.95	506.25	505.86
HF, bridge to approach, ft	0.17	0.21	0.21
Elevation of WS immediately US, ft	503.78	506.04	505.65
ya, depth immediately US, ft	7.308531	9.568531	9.178531
ya, depth immediately US, m	2.271141	2.97344	2.852247
Mean elev. of deck, ft	509.31	509.31	509.31
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	0.966848	0.893255	0.906164
Ys, depth of scour (chang), ft	-1.66608	0.776475	0.512524

ARMORING			
D90	0.816	0.816	0.816
D95	1.076	1.076	1.076
Critical grain size,Dc, ft	0.2137	0.4481	0.4189
Decimal-percent coarser than Dc	0.543	0.267	0.288
Depth to armoring,ft	0.54	3.69	3.11

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	750	1100	1050	750	1100	1050
a', abut.length blocking flow, ft	9.5	11.1	10.9	1.3	4.6	4
Ae, area of blocked flow ft2	33.4	52	53.1	5.7	17.3	15.3
Qe, discharge blocked abut.,cfs	119.5	--	210	13.9	39.5	35
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve manually)						
Ve, (Qe/Ae), ft/s	3.58	3.96	3.95	2.44	2.28	2.29
ya, depth of f/p flow, ft	3.52	4.68	4.87	4.38	3.76	3.83
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	135	135	135	45	45	45
K2	1.05	1.05	1.05	0.91	0.91	0.91
Fr, froude number f/p flow	0.336	0.307	0.316	0.205	0.207	0.206
ys, scour depth, ft	8.96	11.17	11.56	6.07	6.43	6.36

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	9.5	11.1	10.9	1.3	4.6	4
y1 (depth f/p flow, ft)	3.52	4.68	4.87	4.38	3.76	3.83
a'/y1	2.70	2.37	2.24	0.30	1.22	1.05
Skew correction (p. 49, fig. 16)	-	-	-	-	-	-
Froude no. f/p flow	0.34	0.31	0.32	0.21	0.21	0.21
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.55	0.8	0.77	0.55	0.8	0.77
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.4	6.4	6.4	6.4	6.4	6.4
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.20	2.53	2.35	1.20	2.53	2.35
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.04	2.21	2.05	1.04	2.21	2.05
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR